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Methodologies
On Calculation of Natural Gas Consumption for Auxiliary Consumption in the Gas Transportation System

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1. General Provisions

1.1 These Methodologies are developed in pursuance of point 1 (I)of Article 28 of the RoA Energy Law with the consideration of structural changes exercised in the RoA Natural Gas Sector and newly commissioned requirements for the normative-technical documentation.

1.2 The main definitions used in these Methodologies are as follows:

- natural gas or gas – natural gas fuel for industrial and utility purposes, having quality characteristics that are defined by the RoA Technical Rules and Procedures

- transporter – a legal entity holding a gas transportation license

- gas transportation system – a unified system of natural gas transportation lines (gasmains), gas distribution stations, underground gas storages and other equipment under control and operation of the Licensee holding a transportation license. By means of this system the natural gas is transported from the import point to the distributor, customer or to the third country.

- gasmain – high pressure gas pipes provided for transportation of natural gas from the RoA import point to the gas distribution plant.

- gas distribution plant (GDP)– a plant provided for delivery of natural gas to the distributor and (or) customers at sizes, pressure and quality characteristics defined by corresponding contracts.

- underground gas storage (UGS) –complex of constructions provided for the regulation of disbalance in the gas consumption and for the long-term storage of natural gas.

- settlement period – a period stated in the contract within which the metering of gas amount delivered (sold) by the transporter to the distributor, consumer is carried out.

- gas flow for ancillary consumption (AC) – consumption of natural gas, conditioned by the operation of gas transportation system, technological processes, mounting and repairing works at own expenses , as well as heating of industrial buildings of the GTS.

1.3. The following conventional values are used in the Methodologies

Conventional value	Parameters	Measure units
V_{geom}	Geometrical volume of the gas pipe	m^3
P	Exclusive gas pressure	MPa
P_{atm}	Atmospheric pressure	MPa
P_{st}	Exclusive gas pressure in standard conditions	MPa
t	Gas temperature	°C
T	Thermodynamic temperature of gas	K
T_{st}	Thermodynamic temperature of gas in standard conditions	K

Z	Gas compression factor	-

1.4. The basic principles of calculation of natural gas for ancillary consumption in the gas transportation system and the corresponding calculation formulas are provided in these Methodologies.

1.5. The following two types of calculations shall be done by means of these Methodologies:

- the calculation implemented based on the prospective forecast basic data which are used in the first planing period (month, year) for the determination of the specific parameters of natural gas for ancillary consumption;

- the calculation implemented based on the actual basic data for the previous settlement period, which are used to determine the correspondence of the natural gas flow for ancillary consumption with the permissible proportions during the previous settlement period (month, year). The results of this calculation are used in the process of analysis of balance sheets introduced by all economic entities implementing natural gas transportation, and evaluation of their operation efficiency.

2. Methodologies of Calculation of Natural Gas Flow in the GTS for Ancillary Consumption

In the gas transportation system the natural gas flow for the ancillary consumption (V_{AC}) is determined by the following formula:

$$V_{AC} = V_{B} + V_{Air} + V_{RM} + V_{SD} + V_{ú} + V_{MC} + V_{H} + V_{US} \quad \text{thous. m}^3, (1),$$

where

B – gas consumption conditioned by blowing up of gasmains for the purpose of their regular cleaning from solid particles, condensate and remainder of water

Air – gas consumption conditioned by blowing process implemented to force out the air from the newly commissioned gas pipes, in thous. m^3.

RM – gas consumption conditioned by emptying the separate parts of gas pipes during the repairing and mounting operations of the acting gas pipelines and their blowing up after the accomplishment of such operations, in thous. m^3.

SD – conditioned by blowing up of the steam traps and duster catchers, in thous. m^3

O – gas consumption conditioned by injection of odorant, in thous. m^3

MC – gas consumption conditioned by blowing up of pulsed lines of the automation and metering-controlling devices, in thous. m^3

H – gas consumption conditioned by operation of the underground gas storage plants, in thous. m^3, (includes all above elements, as well as fuel gas consumption and consumption of gas associated with the technological needs and commissioning and decommissioning of units).

2.1. Gas consumption conditioned by blowing up of gasmains for the purpose of their regular cleaning from solid particles, condensate and remainder of water

During the operation of the gas transportation system the gas consumption conditioned by blowing up of gasmains is calculated based on the parameters of gas flow critical regime, taking into consideration the duration of blowing up process and the surface of the gas pipe or the bleeder by means of which emission of gas takes place. This is defined by the following formula [1;2]:

$$V_{B} = A_{B} \sum_{i=1}^{n_B} \left(D_{Bi}^{2} \; P_{Bi}^{av} \; t_{Bi} \; N_{Bi} \right) \quad \text{thous. m}^3, \qquad (2)$$

where,

A_B – a constant factor, which takes into consideration the critical regime of gas outflow and is equal to 2.37 m/MPa sec.

D_{Bi} - internal diameter of the i^{th} section of the gas bleeder (pipe), through which the emission of gas takes place, m.

P_{Bi}^{av} – the average pressure of gas before the outflow section of the i^{th} blow cleaned part of the gas pipe, MPa.

τ_{Bi} – duration of blowing up process of the i^{th} section of the gas pipe, sec.

N_{Bi} – number of blowing processes of the i^{th} section of the gas pipe within the settlement period.

n_B - number of blow cleaned sections within the settlement periods.

2.2. Gas consumption conditioned by blowing process implemented to push out the air from the newly commissioned gas pipes

The maximal amount of gas consumed for pushing out the air from the newly commissioned gas pipes is accepted equal to the twofold of geometrical value [2] and should be determined by the following formula:

$$V_{air} = 2 \quad 10^{3} \sum_{i=1}^{n_{air}} V_{geomi} \quad \text{thous. m}^3 \qquad (4)$$

where,

n_{air} – number of gas pipes newly commissioned during the settlement period

2.3. Consumption of gas during the repairing and mounting operations of the acting gas pipelines implemented at the own expenses

The aggregate amount of gas consumption conditioned by repairing and mounting works implemented on the acting gas pipes during the settlement period is determined in the following way:

$$V_{RM} = \sum_{i=1}^{n_{RM}} \left(V_{empti} + V_{Bi}\right) \quad \text{thous. m}^3, \qquad (5)$$

where,

V_{empi} – amount of gas emission exhausted due to emptying of the i^{th} section, during which the gas pressure reduces to the level of atmospheric pressure or to the possible least value, thous. m^3

V_{Bi} – gas consumption conditioned by blowing up process implementing to push out the gas-air mixture from the ith section of the gas pipe after the repairing and mounting works are accomplished.

The volume of gas consumed due to emptying process is calculated by the following formula [2], as the volume of gas within the given section adjusted to the standard conditions:

$$V_{\text{empt}} = A_{\text{empt}} \quad \frac{D^2 \quad \ell}{T} \quad \frac{P}{Z} \quad P_{\text{atm}} \qquad \text{thous. m}^3 \qquad (6)$$

A_{emt} - a constant factor under standard conditions, which is equal to 2270 K/MPa

D – internal diameter of the emptying section of the gas pipe, m

l - length of the emptying section of the gas pipe, km

T – gas temperature in the emptying section, K

P – gas pressure before the process of emptying, MPa

Z – gas compression factor in the emptying section, (7)

The consumption of gas (V_B), for the purpose of elimination of the gas-air mixture by blowing it up after the accomplishment of the repairing and mounting works, is determined by formula (4).

2.4. Gas consumption conditioned by blowing up of the steam traps and duster catchers

The consumption of gas during the process of blowing up of the steam traps and duster catchers is conditioned by the following elements:

- the amount of gas outflowed during the closing of the blowing pipe after elimination of the condensate,
- the volume of gas consumed in connection with the degassing of the eliminating condensate,

and is determined by the formula [2]:

$$V_{\text{CB}} = 10 \quad ^3 \quad \overset{n_{\text{CB}}}{\underset{i=1}{?}} \quad \frac{B \quad f_i \quad P_{\text{CBi}}^{\text{av}} \quad m_{\text{CBi}} \quad t_{\text{Bi}}}{T_i \quad Z_i} + C_{ki} \qquad \text{thous. m}^3, \qquad (7)$$

where,
n_{CB} – number of devices subject to blowing up within the settlement period

B – a constant factor equal to 93.4 10^4 m K/MPa sec

f_I – internal surface of section of the pipe pushing out the gas in the ith blow cleaned device, m^2

P^{av}_{CBi} – average pressure of gas before the outflow section of the i^{th} blow cleaned device, MPa

m_{CB} - number of blowing processes that the i^{th} blow cleaned device undergone during the settlement period

τ_{CBi} – closing period of the valve within the i^{th} blow cleaned device, which starts from the moment of outflow of gas, sec.

T_i – gas temperature in the i^{th} blow cleaned device, K

Z_i – compression factor in the i^{th} blow cleaned device, [7]

C_k – gas loss associated with the degassing of the condensate, which is usually accepted as 1,65 m^3 for one automated blowing and 3.2 m^3 for one mechanical blowing [2].

2.5. Gas consumption conditioned by the injection of odorant

Gas consumption conditioned by the injection of odorant is determined considering the norm of gas consumption during the process of injection and the actual parameters of gas in the gas pipe, by the following formula [2]:

$$V_{ú} = A_{û} \quad V_{û} \quad V_{o}^{norm} \quad \frac{P_{û}^{av}}{Z_{û}^{av} \quad T_{û}^{av}} \quad \text{thous. m}^3, \ (8),$$

where,

A_o – a constant factor equal to 7.813 10^{-7} t K/MPa m^3, when for odorization of 1000 m^3 of natural gas 16 g of odorant is needed.

V_o - volume of gas to be odorized, thous. m^3
V_o^{norm} – volume of gas consumed during the injection of 1 t of odorant into the natural gas having the parameters P=5.4 MPa and T=293.15° K,. According to formula [2] this value equals to 55.9 m^3/t

P_o^{av} - average pressure of gas in the gas pipe during the odorization, MPa

Z_o^{av} – average compression factor during the injection of odorant

T_o^{av} – average temperature during the injection of odorant, K

2.6. Consumption of gas conditioned by operation of metering-controlling devices and automation means

Consumption of gas conditioned by operation of metering-controlling devices and automation means depends on the blowing of pulsed lines. It is calculated by the following formula [1]:

$$V_{\mathrm{MC}} = A_{\mathrm{MC}} \quad P_{\mathrm{MC}}^{\mathrm{av}} \quad t_{\mathrm{MC}} \quad n_{\mathrm{MC}} \quad m_{\mathrm{MC}} \quad 10^{\ 3} \quad \text{thous. m}^3 \qquad (9)$$

where

A_{MC} – a constant factor, which considers the outflow regime of gas and equals to 0.176 m^3/MPa sec, when d_{puls} = 10 mm.

P_{MC}^{av} - average pressure of gas in the pulsed lines of the MC and Automation devices, MPa.

t_{MC} - duration of blowing process in the MC and A devices, sec

n_{MC} - frequency of blowing up of MC and A devices in the settlement period,

m_{MC} - total number of MC and A devices

2.7. Consumption of gas conditioned by heating of technological buildings and constructions

The seasonal consumption of gas conditioned by heating of technological buildings and constructions of the GTS is formulated as follow [1]:

$$V_{\mathrm{H}} = \frac{3.6 \quad Q_{\mathrm{Hd}}^{\mathrm{S}}}{q_{\mathrm{sl}} \quad h_{\mathrm{b}}} \quad \text{thous. m}^3, \qquad (10)$$

where,

Q^{s}_{Hd} - seasonal heat demand of the heating system , kWh
q_{sl} – lower specific emission of gas, kJ/m^3

h_b - average efficiency factor of heating boilers

The seasonal heat demand of the heating system is determined by the following formula [1]:

$$\mathrm{Q}_{\mathrm{Hi}}^{\mathrm{S}} = \sum_{i=1}^{m_{\mathrm{h}}} \mathrm{Q}_{\mathrm{Hi}}^{\mathrm{S}} = 24 \sum_{i=1}^{m_{\mathrm{H}}} \frac{t_{\mathrm{i}}^{\mathrm{ins}} \quad t_{\mathrm{av}}^{\mathrm{out}}}{t_{i}^{\mathrm{ins}} \quad t^{\mathrm{set}}} \quad \mathrm{Q}_{i} \quad n_{i}^{\mathrm{H}} \quad \text{kWh}, \qquad (11)$$

where,

Q_{Hi}^{S} - the seasonal heat demand of the heating system of the i^th^ building of the given area , kWh.

m_H – number of heated buildings and constructions, items

t_i^{ins} - the average temperature inside the i^th^ building of the given area during the heating season, °C

t_{av}^{out} - the average temperature outside the given area during the heating season, °C

t^{set} – the settlement temperature outside the given area, °C

Q^l – the settlement heat load of the heating system of the i^th^ building of the given area, kW

n_i^H - number of days during which the i^th^ building of the given area is heated, day.

The settlement heat load of the heating system of the i^th^ building of the given area is determined by the following formula [1]:

$$Q_i = \left(1 + m_i^{i}\right) \quad q_{0i} \quad V_{bi} \quad \left(t_i^{ins} \quad t^{set}\right) \quad a \quad \text{kW}, \qquad (12)$$

where,

m_i^i - infiltration factor of the i^th^ building

q_{oi} – the specific heat characteristic of the i^th^ building or construction, W/m^3 °C

V_{bi} – the geometrical volume of the i^th^ building or construction by outside dimensions, thous. m^3

a - direction factor

The infiltration factor in formula (12) takes into consideration the heat consumed for heating of the outside air penetrating through the leakages between constructions and is calculated by the following formula [1]:

$$m_i^{i} = b \quad \sqrt{2 \quad g \quad H_i \quad\quad 1 \quad \frac{t^{set} + 273.15}{t_i^{ins} + 273.15} \quad + w_i^2} \qquad (13)$$

where,

b – the infiltration constant, b= 0.008 ÷ 0.01 sec/m, [1];

g – gravitational acceleration, m/sec^2

H_I – height of the i^th^ building or construction , m

Wi – the settlement acceleration of the wind in the given area during the coldest period of the year, m/sec

The specific heat characteristic of the building in formula (12) depends on the geometric volume of the building and based on formula [1] has the following constant values:

V_{bi}	<5 thous. m^3	5-10 thous. m^3	10-15 thous. m^3	$\geq$ 15 thous. m^3
q^{oi}	0.5	0.44	0.41	0.37

The α direction factor considers the change of the specific hating characteristic of the building or constructions, which depends on climate conditions (the settlement temperature outside the buildings) and based on formula [1] has the following constant values:

t^{set} (°C)	-10	-15	-20	-25	-30	-35
α	1.45	1.29	1.17	1.08	1.00	0.95

2.8. Consumption of gas conditioned by the operation of the underground gas storages

Consumption of gas for the operation of the gas storages is determined by the formula:

$$V_{USP} = V_{fg} + V_{c} + V_{d} + V_{com} \quad \text{thous. m}^3 \qquad (14)$$

where,

V_{fg} –consumption of fuel gas in the compressor plant, thous. m^3

V_{c}, V_{d} – consumption of gas conditioned by start-up and shutdown of compressors, which is calculated as the volume of gas pushed out from the compressors and border gas pipes, considering their geometric volumes and parameters of gas, thous. m^3.

V_{com} –consumption of gas emitted to the atmosphere through the pumps and leakages of connecting gas pipes during inflation of gas , thous. m^3 .

2.8.1. Consumption of fuel gas in the compressor plant

The consumption of gas during the inflation of gas into the gas wells is calculated by the following formula [3]:

$$V_{fg} = \sum_{i=1}^{k} \left(V_i^{fg} \quad t_i^{fg}\right) \quad \text{thous.m}^3 \qquad (15),$$

where,

V_i^{fg} - consumption of fuel gas in the i[th] unit of the compressor plant, thous. m^3/h,

t_i^{fg} - time of operation of the i[th] unit of the compressor plant during the reporting period, hours.

k – number of acting units of the compressor plant during the settlement period, items.

The consumption of fuel gas per unit equals to [3] :

$$V^{fg} = V^{fg}_{nom} \quad \left(\frac{W_{av}}{W_{nom}}\right)^{a} \quad \frac{Q_{nom}}{Q_{Act}} \quad \frac{\text{thous.m}^3}{\text{hour}}, \qquad (16),$$

where,

V^{fg}_{nom} - the nominal consumption of fuel gas (considering the technical condition of the unit), it equals to 0.41 thous. m^3 /h, [3]

W_{nom} – the nominal capacity of the compressor engine [5], kW

W_{av} – the actual average capacity of the compressor engine during the settlement period, kW

Q_{nom} – the nominal lower thermal output during the combustion of fuel gas, which is equal to 34500 kJ/m^3, according to formula [3].

Q_{act} - the actual lower thermal output during the combustion of fuel gas in standard conditions, kJ/m^3

a – a factor, which considers the loading of one compressor, a=0.359, [3].

The actual average capacity of the compressor engine during the settlement period is determined by the following formula [3]:

$$W_{av} = \frac{4340 \quad P^{ent}_{av} \quad Q_{cap}}{h_{ad}} \quad \left(e^{0.245} \quad 1\right) \quad \text{kW}, \qquad (17),$$

where,

P^{ent}_{av} - the average pressure of gas at the entry of the compressor during the settlement period, MPa

Q_{cap} – the volumetric capacity of the compressor, m^3/sec

ε - the level of increase of gas pressure in the compressor, which depends on the relation of the average pressures at the entry and exit of the compressor [3],

η_{ad} – adiabatic efficiency factor which , according to ε, equals to [3]:

ε	$\varepsilon = 1.3 \div 1.5$	$\varepsilon = 1.51 \div 1.7$	$\varepsilon = 1.71 \div 2.5$
η_{ad}	$\eta_{ad} = 0.8 \div 0.82$	$\eta_{ad} = 0.82 \div 0.85$	$\eta_{ad} = 0.85 \div 0.88$

The volumetric capacity of the compressor in the formula (17) is determined by the formula [8]:

$$Q_{cap} = 0.24 \quad v_{dis} \quad n_{sh} \quad 1 \quad a_{clear} \quad \frac{Z_{entry}}{Z_{exit}} \quad e^{0.755} \quad 1 \qquad \frac{m^3}{sec}, \qquad (18)$$

where,

v_w – compressor displacement per one revolution, m^3

n_{sh} – frequency of the compressor shaft, sec^{-1}

Z_{entry} , Z_{exit} – gas compression factors at the entry and exit, respectively [7],

a_{clear} – the aggregate relative volume of the cylinder clearance space, which is determined by the following formula [3]:

$$a_{clear} = \frac{a_{self} \quad v_{dis} + v_r}{v_{dis}}, \qquad (19)$$

where,

a_{self} – the relative self-space of the cylinder displacement,

v_r - the aggregate volume of the capacity regulators connected during the operation, m^3

2.8.2. Consumption of gas conditioned by unscheduled start-ups and shutdowns of the compressor plant

a) consumption of gas during the unscheduled start-up of the compressor plant

This consumption of gas is determined as the volume of gas pushed out from the compressors and border gas pipes and equals to the double value of their geometrical volume [4]:

$$V_{st} = 2 \quad 10^{3} \sum_{i=1}^{k} \left(V_i^{comp} \quad n_i^{st} \right) \text{ thous. } m^3, \qquad (20)$$

V_i^{comp} - the geometrical volume of the lower and connective pipes at the compressor’s ith unit entry and exit, m^3

n_i^{st} - number of start-ups of the compressor’s ith unit,

k - number of working units of the compressor plant during the settlement period.

b) consumption of gas during the unscheduled shutdowns of the compressor plant

It is determined as the volume of gas pushed out from the compressors and border gas pipes dependent not only on their geometrical volume, but also on the gas parameters, and is determined by the following formula [4]:

$$V_{\mathrm{sh}} = A_{\mathrm{sh}} \sum_{i=1}^{k} \frac{V_i^{\mathrm{comp}}}{T_i^{\mathrm{av}}} \quad \frac{P_i^{\mathrm{av}}}{Z_i^{\mathrm{av}}} \quad P_{\mathrm{atm}} \quad m_i^{\mathrm{comp}} \quad \text{thous. m}^3, \qquad (21)$$

where,

A_{sh} – a constant factor equal to 2.8919 K/MPa,

P_i^{av} - the average pressure of gas at the entry (exit) of the ith unit of the compressor plant

T_i^{av} - the average temperature of gas at the entry (exit) of the ith unit of the compressor plant

Z_i^{av} - the compression factor at the entry (exit) of the ith unit of the compressor plant under the conditions of P_i^{av}, T_i^{av}, [7].

m_i^{comp} - number of shutdowns of the ith unit of the compressor plant during the reporting period,

k – number of working units of the compressor plant during the reporting period, items

2.8.3. <u>Consumption of gas emitted into the atmosphere through the leakages of connective gas pipes and gas motor compressor during the inflation of gas into the underground gas storage plant</u>

Consumption of gas emitted into the atmosphere through the leakages of connective gas pipes and gas motor compressor during the inflation of gas into the underground gas storage plant is determined by the following formula [3]:

$$V_{comp} = q_{t.p} \quad W_{nom.} \sum_{i=1}^{k} t_i^{fg} \quad 10^{3} \ \text{thous. m}^3, \qquad (22)$$

where,

$q_{t.p.}$ – the specific consumption of gas for the technological purposes under the condition of the average pressure in the compressor plant equal to $q_{t.p.} = 0.03$ m^3/kWh,

W_{nom} – the nominal capacity of the compressor engine [5], kW.

t_i^{fg} - time of operation of the i^{th} unit of the compressor plant during the reporting period, hours.

k – number of acting units of the compressor plant during the reporting period, items.